Hayabusa Reentry: Trajectory Analysis and Observation Mission Design

Alan M. Cassell[1], Gary A. Allen[2], Jay H. Grinstead[3]
NASA Ames Research Center, Moffett Field, CA 94035-1000

Manny E. Antimisiaris[4]
NASA Dryden Flight Research Center, PO Box 273, Edwards, CA 93523-0273

Jim Albers[5], Petrus M. Jenniskens[6]
SETI Institute, 189 Bernardo Avenue, Mountain View, CA 94043

On June 13th, 2010, the Hayabusa Sample Return Capsule (SRC) successfully re-entered Earth's atmosphere over the Woomera Prohibited Area (WPA) in southern Australia in its quest to return fragments from the asteroid 1998 SF36 "Itokawa". The SRC entered the atmosphere at a super-orbital velocity of 12.04 km/sec (inertial), making it the second fastest human-made object to traverse the atmosphere. The NASA DC-8 airborne observatory was utilized as an instrument platform to record the luminous portion of the SRC re-entry (~60 sec) with a variety of on-board instruments to capture the ultraviolet to near-IR wavelength regime. The predicted SRC entry state information at ~200 km altitude was propagated through the atmosphere to generate aerothermodynamic and trajectory data used in the initial observation flight path design and planning. The DC-8 flight path was designed by considering safety, optimal SRC viewing geometry and aircraft capabilities in concert with the predicted SRC trajectory. Subsequent entry state vector updates provided by the Deep Space Network (DSN) team at the Jet Propulsion Laboratory (JPL) were analyzed after the planned trajectory correction maneuvers (TCMs) to further refine the DC-8 observation flight path. Primary and alternate observation flight paths were generated during the mission planning phase which required coordination with Australian authorities for pre-mission approval. The final planned observation flight path was chosen based upon trade-offs between optimal viewing requirements, ground based observer locations (to facilitate post-flight trajectory reconstruction), predicted weather in the WPA and constraints imposed by flight path filing deadlines with the Australian authorities. To facilitate SRC tracking by the instrument operators, a series of two racetrack flight path patterns were performed prior to the observation leg so the instruments could be pointed towards the region in the star background where the SRC was expected to become visible. Initial post-flight trajectory reconstruction indicates the predicted trajectory was very close to the as-flown trajectory. An overview of the design methodologies and trade-offs used in the Hayabusa reentry observation campaign along with lessons learned will be presented.

Nomenclature

ARC	=	Ames Research Center
DFRC	=	Dryden Flight Research Center
JAXA	=	Japanese Aerospace Exploration Agency
JPL	=	Jet Propulsion Laboratory
DSN	=	Deep Space Network
EFPA	=	Entry Flight Path Angle
SRC	=	Sample Return Capsule

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[1] Systems Engineer, ERC Inc., Entry Systems and Vehicle Development Branch, M/S 229-1, Associate Member.
[2] Aerospace Engineer, ERC Inc., Aerothermodynamics Branch, M/S 230-4,
[3] Project Manager, Aerothermodynamics Branch, M/S 230-4, Associate Fellow.
[4] Navigator, Entry Systems and Technology Division, IPA University of California Santa Cruz, Fellow.
[5] Systems Engineer, Aerothermodynamics Branch, M/S 230-3, Associate Member.
[6] Principal Investigator, Associate Fellow.

TCM	=	Trajectory Correction Maneuver
TPS	=	Thermal Protection System
WPA	=	Woomera Prohibited Area
EDL	=	Entry, Descent and Landing